ETE Update: ADS Testing of C4ISR Systems
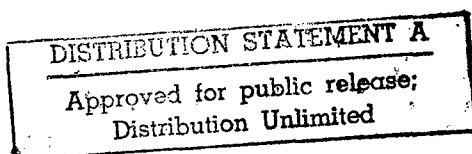
A Technical Paper
    from the
Joint
  Advanced
    Distributed
      Simulation
        Joint Test Force

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ETE Update - ADS Testing of C4ISR Systems

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ABSTRACT

The End-To-End (ETE) Test, conducted under the auspices of the Department of Defense Joint Advanced Distributed Simulation (JADS) Joint Test and Evaluation (JT&E), is currently developing a synthetic test environment that can be used for future operational testing and doctrinal development. This synthetic test environment will be used initially to conduct developmental and operational testing of the Joint Surveillance Target Attack Radar System (Joint STARS). As designed and built, it may be used to conduct future testing of systems such as the Common Ground Station (CGS), the All Source Analysis System (ASAS), and the Block II Army Tactical Missile System.

This paper will describe progress to date, to include the results of our initial operational and developmental tests, lessons learned to date, and experience gained in verifying and validating a synthetic test environment using the Department of Defense Verification, Validation and Accreditation (VV&A) Recommended Practices Guide.

Background

The Joint Advanced Distributed Simulation (JADS) Joint Test and Evaluation (JT&E) was chartered by the Office of the Under Secretary of Defense (Acquisition and Technology), Office of the Director, Test and Evaluation "...to investigate the utility of Advanced Distributed Simulation (ADS) for both developmental test and evaluation (DT&E) and operational test and evaluation (OT&E). JADS will investigate the present utility of ADS, including Distributed Interactive Simulation, for test and evaluation (T&E); and finally, identify the requirements that must be introduced in ADS systems if they are to support a more complete T&E capability in the future."

The End-To-End (ETE) Test is one of the three tests within the JADS JT&E program. The ETE Test is designed to evaluate the utility of ADS to support the testing of a C4ISR system, the Joint Surveillance Target Attack Radar System (Joint STARS), while the system performs the end-to-end loop of detect, track, target, cue a weapons system, and assess battle damage.

Joint STARS is composed of both an airborne and ground segment along with the necessary communications subsystems. The E-8 airborne system and the Ground Station Modules (GSM) together provide the surveillance, target detection, and tracking required to assist commanders in understanding the enemy situation and taking action to destroy enemy forces.

To support the ETE Test, a simulation called the Virtual Surveillance Target Attack Radar Sensor (VSTARS) was designed by JADS and built by Northrop Grumman, Lockheed Martin, and Motorola. VSTARS is capable of functioning in a pure laboratory environment using commercial off the shelf (COTS) equipment, in a hardware in the loop environment using fielded components (Primary Mission Equipment (PME)), and onboard the aircraft coexisting with the real radar subsystem in an ADS augmented environment.

The ETE Test uses some of the developmental and operational test issues for the Joint Surveillance Target Attack Radar System (Joint STARS) to conduct its T&E utility evaluation in an ADS-enhanced test environment. Additionally, the ETE Test will also conduct an evaluation of the JADS Test Control and Analysis Center's (TCAC) capability to control a distributed test of this type and remotely monitor and analyze test results.

The ETE Test consists of four phases. Phase 1 developed VSTARS and modified or developed the components required to establish the synthetic environment (SE). A copy of the Phase 1 final report is available on the JADS web site. Phase 2 conducted the VV&A of the SE and evaluated the utility of ADS to support DT&E and early OT&E of a C4ISR system in a laboratory environment. A copy of the Phase 2 final report will be on the JADS web site in the near future. Phase 3 will transition the radar emulation portion of VSTARS to the E-8C and repeat the VV&A. Phase 4 evaluates the ability to perform OT&E of Joint STARS in a synthetically enhanced operational environment.

As stated in the abstract, this paper will present some of the results of our initial operational and developmental tests, lessons learned to date, and experience gained in verifying and validating a synthetic test environment using the <u>Department of Defense Verification, Validation and Accreditation (VV&A) Recommended Practices Guide</u>.

Verification, Validation and Accreditation (VV&A)

One of the major issues associated with the use of Advanced Distributed Simulation (ADS) is the credibility of the models and simulations (M&S) used and the credibility of their interactions over a distributed network. The credibility of M&S is commonly measured by verification and validation (V&V) and then formally approved as adequate for use for a specific application by accreditation. The V&V of M&S and distributed simulations is formally required by Department of Defense (DoD) Instruction 5000.61 prior to their use in testing.

The basis for the VV&A of the Phase 2 SE was the <u>Department of Defense Verification, Validation and Accreditation (VV&A) Recommended Practices Guide</u> and, since the ETE Test utilizes the Institute of Electrical and Electronics Engineers (IEEE) Standard 1278 for Distributed Interactive Simulation (DIS) to develop its ADS SE, use was also made of the <u>Recommended Practice for Distributed Interactive Simulation -- Verification, Validation, and Accreditation (Draft-4 November 1996)</u>.

The V&V of the components of the SE and the SE itself was focused upon the functional requirements and acceptability criteria from the test plan and other documents that describes the SE. This allowed the V&V agent to focus his efforts on those requirements critical to the conduct of the ETE Test and enabled him to develop the V&V plan by identifying the tasks required to meet these requirements and acceptability criteria. The V&V plan was developed in a manner that matched and complemented the test activity plan, test requirements, component requirements, available resources, and timelines for the test.

The results of the V&V were presented to an accreditation board composed of DoD and Multi-Service representatives and the ETE Test SE was accredited for use in the Phase 2 OT Test by the Director of JADS, Col Mark Smith. Associated plans, results, and briefings may be accessed on the JADS web site.

VV&A Lessons Learned

With the publication of the <u>Department of Defense Verification, Validation and Accreditation (VV&A) Recommended Practices Guide</u> and other guides, such as the <u>Recommended Practice for Distributed Interactive Simulation -- Verification, Validation, and Accreditation (Draft-4 November 1996)</u>, there exists a plethora of processes and practices. The difficulty lies in applying them to your particular program as executable tasks at the appropriate stages of your test. The solution arrived at by the ETE V&V team was to join the crowd and develop our own JADS ETE Test VV&A Process Model.
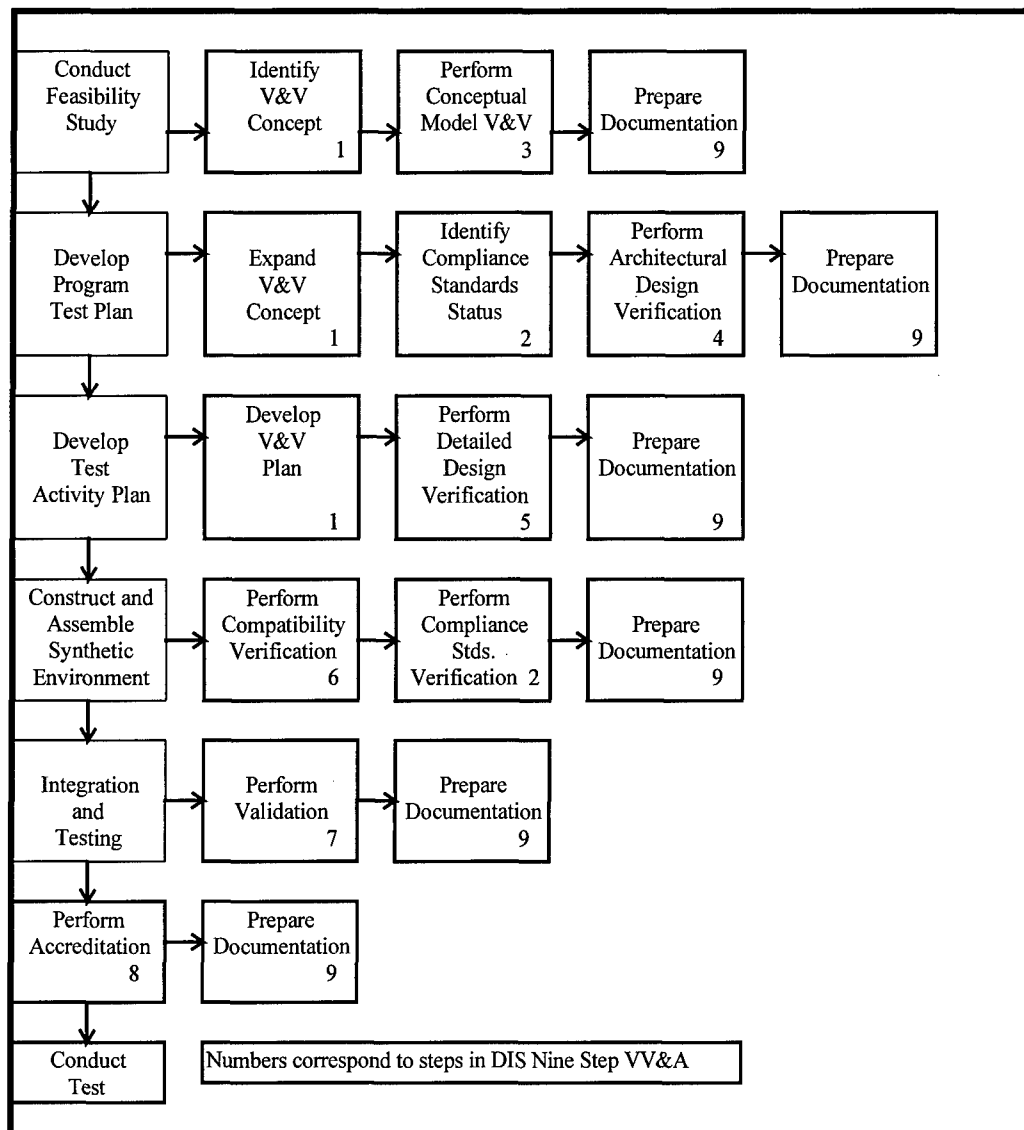
Conduct Feasibility Study → Identify V&V Concept 1 → Perform Conceptual Model V&V 3 → Prepare Documentation 9

Develop Program Test Plan → Expand V&V Concept 1 → Identify Compliance Standards Status 2 → Perform Architectural Design Verification 4 → Prepare Documentation 9

Develop Test Activity Plan → Develop V&V Plan 1 → Perform Detailed Design Verification 5 → Prepare Documentation 9

Construct and Assemble Synthetic Environment → Perform Compatibility Verification 6 → Perform Compliance Stds. Verification 2 → Prepare Documentation 9

Integration and Testing → Perform Validation 7 → Prepare Documentation 9

Perform Accreditation 8 → Prepare Documentation 9

Conduct Test

Numbers correspond to steps in DIS Nine Step VV&A

Figure 1. JADS ETE Test VV&A Process Model

In the JADS ETE Test VV&A Process Model, test events, which consist of the planning, construction and assembling of the SE, integration and testing of the SE, accreditation of the SE, and conduct of the test all proceed on the left side from top to bottom. The V&V events, to include documentation, proceed to the right for each test event.

We also learned, or relearned, that V&V cannot be economically and efficiently performed without a set of documented requirements and acceptance criteria. We learned this the hard way because up to the point of writing the V&V plan, we had never sat and written down the requirements and acceptability criteria for the SE and its components. They existed as requirements, but were scattered in various plans, documents, and statements of work. More importantly, what was acceptable did not exist in most cases and needed to be developed before V&V could begin. It is one thing to say that you require the simulation to simulate the radar onboard the E-8C. It is much more difficult to say what is acceptable. Acceptability criteria are the specifications the modeler must meet. Likewise, these criteria must be known before V&V begins in order to scope the cost and level of effort of the V&V.

As an example, we used an existing constructive simulation (Janus) to provide Entity State Protocol Data Units (ESPDU) to VSTARS. All VSTARS needed was what kind of entity was it, where is it at, and if moving, how fast is it moving and in what direction. This meant that we did not need to verify and validate the acquisition algorithm in the simulation, nor did we need to worry about direct fire engagement outcomes. As a result, our V&V of this component of the SE was economically and efficiently performed.

Finally, we learned that in order for V&V to be economically and efficiently performed, it must be done in conjunction with the construction and assembly of the SE and the integration and testing of the SE. The costs and effort involved in activating the SE prohibit its activation for the purposes of V&V alone. In addition, by doing V&V in this manner, V&V becomes a continuous quality check on the SE and a tool that continues to be used even after accreditation. The results of the Phase 2 OT were validated by reviewing the data and applying the V&V measures to ensure the SE behaved as expected.

Developmental Testing Lessons Learned

VSTARS was designed so that the only simulation taking place is the simulation of the MTI and SAR radar modes within the radar subsystem. Everything else is either integration code or actual E-8C system code. The inputs into VSTARS, except for the target data, are normal inputs into the real radar processor and the outputs are the actual radar reports. The radar simulations are parallel processes with the radar when live and virtual are mixed and solve the radar equations in order to achieve the required fidelity.

This architecture allows the use of VSTARS to conduct developmental testing of all of the other subsystems that comprise Joint STARS, provided that VSTARS is an accurate representation of the radar. Obviously, VSTARS cannot be used to conduct developmental testing of the radar subsystem.

As an example, one of the features of the workstation used on the E-8C is an automatic tracker (A-Tracker). The A-Tracker works off radar reports and when initiated, will automatically track a designated formation, providing bearing, speed, and number of vehicles. Previous to VSTARS, it was necessary to either have a functioning radar (test flight) or a recording of a functioning radar in order to test the A-Tracker. Test cases were basically limited to those that could be achieved at Eglin AFB with a minimal number of vehicles traveling under peacetime safety restrictions.

Northrop Grumman is currently developing an annual release of the radar software that will incorporate a revised version of the A-Tracker software. This provided JADS with the opportunity to ask Northrop Grumman to conduct an ad hoc study, parallel to the normal testing of the new A-Tracker software, to determine if it would be possible to use VSTARS to test this software.

Numerous problems were experienced due to the ad hoc nature of the study, both in the areas of software integration and scenario generation. Additionally, the V&V of VSTARS had not yet been completed and thus no results could be used as documentation for the annual release. Despite these problems, several lessons learned resulted from this study.

- Test cases could be "flown" using VSTARS whenever needed with as many repetitions as desired. This was possible without competing for scarce test aircraft and range resources.
- There was a potential for enormous cost savings. One tester and two computers in a lab vice the aircraft, testers, crew, and range assets required for a live test.
- Any conceivable test case could be "flown" in the laboratory without worrying about safety or limited assets, provided the appropriate scenario generator was available.
- Bad software could be quickly discarded and new software could be tried the next day.
- Most importantly, when a live test flight is flown, as it must be, the testers can be reasonably sure that they will get the maximum value from the flight and test conditions.

Operational Testing Lessons Learned

The Phase 2 Operational Test conducted by the JADS ETE Test Team was designed to determine the utility of ADS to support early OT&E of a C4ISR system in a laboratory environment. The synthetic environment developed to support the test is shown below as Figure 2. Overview of Phase 2 ETE Test Synthetic Environment.
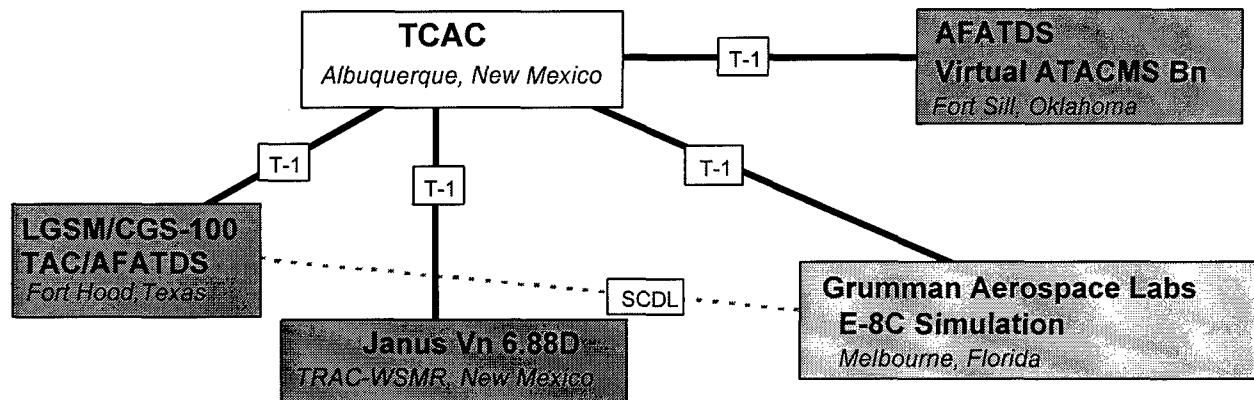

Figure 3. Overview of Phase 2 ETE Test Synthetic Environment

The ETE test used a DIS compatible Janus to generate nearly 10,000 entities representing the elements in the rear of a threat force. TRAC-WSMR, at White Sands Missile Range, New Mexico, provided the Janus scenario feed to VSTARS. The Test Control and Analysis Center, in Albuquerque, New Mexico, provided test control. The JADS Network and Engineering Team monitored the health of the ETE test network, and ensured that adequate data flowed in support of the test. VSTARS, as previously described, provided the emulation of the E-8C from the Grumman Aerospace Labs.

The target analysis cell (TAC), fire support (Advanced Field Artillery Tactical Data System, or AFATDS) and a light ground station module (LGSM) were stationed at Fort Hood, Texas. Communications among these C4I systems employed such doctrinally correct means as the CGS-100, a subsystem of the Compartmented All Source Analysis System (ASAS) Message Processing System (CAMPS), ASAS Remote Workstations (RWSs), and Advanced Field Artillery Tactical Data System (AFATDS) message traffic. The Tactical Army Fire Support Model (TAFSM) simulation modeled the Advanced Tactical Missile System (ATACMS) Bn, and sent the fire and detonate PDUs to the Janus Vn 6.88D simulation. In turn, Janus modeled the engagement results and reflected the results in the synthetic environment.

Over 40 test periods of more than seven hours duration were conducted prior to the actual OT. During the actual OT, five seven hour scenarios were ran and data was collected that could be used to evaluate Joint STARS MOT&E measures. Details of the OT and the results of the evaluation of the value of ADS in testing will be available on our web page in the near future.

The most significant finding as a result of this test was that an ADS synthetic environment, such as the ETE Test SE, has significant utility in supporting early OT&E of a C4ISR system in a laboratory environment. Additionally, this environment can be used to conduct early operational assessments, and for the development of tactics, techniques and procedures prior to system testing. The SE also has tremendous utility in test planning, rehearsal, training of test personnel, verification of data sources and data reduction techniques, and the determination of whether adequate data is collected to evaluate the test measures.

The use of an ADS synthetic environment also allows the tester to conduct tests in an environment that is impossible to achieve on the test range. The testing of a system like Joint STARS with a brigade size

force is akin to testing a five ton dump truck with a bucketful of sand. You will be able to tell if the truck runs and can carry sand, but you will be hard pressed to extrapolate your data to make an argument that the truck can carry five tons. The operational testing of large C4ISR systems, such as Joint STARS require a realistic operational environment to stress the system. Short of arranging for a convenient war, an ADS synthetic environment appears to be the only way to achieve this test environment.

It was found that the ETE environment may also be used for testing other systems that requires a Joint Stars C4ISR input. An example is the Block 2 Army Tactical Missile System (ATACMS) that could use the ETE SE as is for OT&E. The only change needed would be to ensure that Janus could handle the Block 2 weapons load.

Finally, the use of an ADS synthetic environment for testing allows repeatability. As an example, let us consider the Joint STARS operational measure, ability to detect an enemy convoy. If measured during a live test, the tester has no way of knowing whether it is a failure of the radar or a failure of the operator. If measured using a SE, data can be collected as to how many repetitions, if ever, it takes before the operator detects the convoy and the test can be repeated with as many operators as you can find. Analysis of this data should give an indication as to where the problem lies.

Advanced Distributed Simulation (ADS) Lessons Learned

Murphy knows how to do ADS Testing. As Hurricane George approached one of our sites (Melbourne, Fl), the service providers decided to readjust our network. The provider in Melbourne accidentally pulled one of our stubs and then promptly sent all of their personnel to assist in hurricane recovery. Four days later we were able to resume testing, resulting in an eventual extension of the test period by four days.

This event is brought up not because it was fun, Florida during a hurricane is anything but fun, but because it emphasizes the need for redundancy and spares when doing distributed testing. Based on the forty plus days of rehearsal, risk reduction tests, and integration testing, we had spare components at various sites to handle anticipated breakdowns. Unfortunately, we did not anticipate Murphy. By the time we had figured out how to reconfigure our network, and received permission to do so from the security gods, the stub was replaced and our original network was back up.

What this means to the distributed tester, is that during meetings of the entire distributed test force, he must have a Murphy meeting. At this meeting the wildest events imaginable must be listed and then a course of action evaluated and decided upon. For many events, such as Florida sinking beneath the sea, there will no work around. For others, such as the event just described, work arounds exist and can at least be planned for and preapproved.

The time used in the SE must be synchronized throughout the distributed test nodes. The ETE test used a time server located at the test control and analysis center (TCAC) that worked very well, and ensured that all nodes were kept to within one millisecond of each other. Having the same time at each test node helped speed up the analysis, and allowed for the development of automated tools to aid in the analysis.

Software must be acquired or written that automatically notifies the tester in a timely manner when there is a network problem. Since most software of this type is intrusive in nature, a balance must be arrived at between how often the network is checked and the network load due to the test. Adequate bandwidth must be available for both needs. In addition, the alarms must be audible alarms because network problems always occur when you are to busy to watch the monitor (Murphy knows how to do ADS Testing).

Use a stepped buildup approach, where each successive ADS test builds on the success of earlier tests. A "test, analyze, fix and build, test" approach as each node of the SE is added, in combination with a structured, independent testing of the network, will greatly improve the chances for successful ADS testing.

Effective data management is critical. ADS tests can and do generate enormous amounts of data at distributed locations. Without careful planning, key data may not be collected and/or transmitted to the analysis center, and data collected at the network nodes may not be in a useful form for centralized analysis. Prior to the beginning of the test, a comprehensive data management plan must clearly identify the data to be collected at each network node, on-site processing of the data, and the data to be transmitted to the analysis center. The data management plan must be rehearsed and refined during the integration tests, risk reduction tests, and rehearsals and adequate time must be allotted for data analysis between ADS test events.

The test director for a distributed test must have a centrally located test control site. This test control site is not necessarily geographically centrally located. Instead it must be electronically centrally located so that it can monitor and control all that occurs within the test. The central control facility must have the display and communications capabilities to know total system health in real time. Total system health includes not only timely and continuous status reporting from the real, virtual, and constructive players, but the data processing and collection system, and the system synchronization mechanism. The central control facility must also support voice communications, conferencing, and a variety of other human-to-human interfaces necessary for adequate test control. Within the ETE Test, the JADS TCAC was this central control facility.

Conclusion

Succinctly put, ADS has significant utility in supporting the testing of C4ISR systems. It enables the tester to explore areas of the system's performance envelope that are unexplorable by conventional means. It may or may not save money, but it will definitely allow the tester to gain the maximum benefit from live test events. It is usually more difficult to do than live testing because it combines elements of both. As evidenced by the Simulation Test and Evaluation Process (STEP), it is the wave of the future and we must learn how to do it efficiently and effectively.

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